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Assessing the Potential of Using Biochar as a Soil Conditioner

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Abstract

© Published under licence by IOP Publishing Ltd. Biochar is a product of pyrolysis of biomass such as plant tissues, manures, sewage sludge, organic fraction of municipal solid wastes etc. Nowadays, biochar is being discussed as an alternative fertilizer that improves the air and water balance of the soil and provides soil microbiota with slow releasing biogenic elements. Many factors such as initial substrate properties, pyrolysis temperature and regime may influence biochar characteristics. In this study, characteristics of the two biochars prepared from chicken manure (ChM) and sewage sludge (SS) at 550 °C were analyzed in order to reveal their agricultural potential. It was found, that the ChM biochar had a pH value of 5.80±0.21, which was 1.6 lower than the pH of the SS sample. The electrical conductivity of the ChM sample was 6 times higher than that of the SS sample, being 6.42±0.30 mS cm-1 and 1.02±0.10 mS•cm-1, respectively. The cation exchange capacity was estimated to be 7.6±0.26 and 45±0.14 cmol•kg-1 in the ChM and SS samples, respectively. In the ChM sample total organic carbon content was 24.93±3.2%, which is nearly twice as large as that in the SS sample (12.36±4.1%), whereas total nitrogen content was estimated to be 0.33±0.03% and 0.10±0.01% for ChM and SS samples, respectively. Using scanning electronic microscopy and laser particle size distribution analysis, it was shown that the SS sample was more homogeneous in its structure and consisted of particles having a lower size of 1 to 200μm with particles of 10 to 100μm being the most frequent, while the ChM sample was nonhomogeneous and its particle size varied between 2 and 2000 μm. To observe the influence on plants, 1% of biochar was added to soil, and wheat seeds were planted. The germination index estimated for soil treated by SS biochar was estimated to be 97%, while that of soil treated by ChM biochar was lower at about 78%.

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References

[1] Schlesinger W H 1986 The Changing Carbon Cycle (New York, NY: Springer New York) Changes in Soil Carbon Storage and Associated Properties with Disturbance and Recovery 194-220

[2] Tan Z, Lin C S K, Ji X and Rainey T J 2017 Returning biochar to fields: A review Appl. Soil Ecol. 116 1-11

[3] Tan X, Liu Y, Gu Y, Xu Y, Zeng G, Hu X, Liu S, Wang X, Liu S and Li J 2016 Biochar-based nano-composites for the decontamination of wastewater: A review Bioresour. Technol. 212 318-33

[4] Lehmann J 2007 A handful of carbon Nature 447 143-4

[5] Lehmann J and Joseph S 2009 Biochar for environmental management: science and technology (Earthscan)

[6] Ladygina N and Rineau F 2013 Biochar and soil biota (Taylor & Francis)

[7] Deluca T H, Mackenzie M D, Gundale M J and Holben W E Wildfire-Produced Charcoal Directly Influences Nitrogen Cycling in Ponderosa Pine Forests

[8] Yanai Y, Toyota K and Okazaki M 2007 Effects of charcoal addition on N 2 O emissions from soil resulting from rewetting air-dried soil in short-term laboratory experiments Soil Sci. Plant Nutr. 53 181-8

[9] Chan K Y, Van Zwieten L, Meszaros I, Downie A and Joseph S 2007 Agronomic values of greenwaste biochar as a soil amendment Aust. J. Soil Res. 45 629

[10] Major J, Rondon M, Molina D, Riha S J and Lehmann J 2010 Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol Plant Soil 333 117-28

[11] Anon 2016 Production and utilization of biochar: A review J. Ind. Eng. Chem. 40 1-15

[12] Gundale M J and DeLuca T H 2006 Charcoal effects on soil solution chemistry and growth of Koeleria macrantha in the ponderosa pine/Douglas-fir ecosystem Biol. Fertil. Soils 43 303-11

[13] Anon 2007 Molecular signature and sources of biochemical recalcitrance of organic C in Amazonian Dark Earths Geochim. Cosmochim. Acta 71 2285-98

[14] Lehmann J, Gaunt J and Rondon M 2006 Mitigation and Adaptation Strategies for Global Change 11 403-427 Bio-char sequestration in terrestrial ecosystems - a review

[15] Lee J W, Hawkins B, Day D M and Reicosky D C 2010 Sustainability: the capacity of smokeless biomass pyrolysis for energy production, global carbon capture and sequestration Energy Environ. Sci. 3 1695

[16] Kuppusamy S, Thavamani P, Megharaj M, Venkateswarlu K and Naidu R 2016 Agronomic and remedial benefits and risks of applying biochar to soil: Current knowledge and future research directions Environ. Int. 87 1-12

[17] Xu X, Zhao Y, Sima J, Zhao L, Mašek O and Cao X 2017 Indispensable role of biochar-inherent mineral constituents in its environmental applications: A review Bioresour. Technol. 241 887-99

[18] Ding Y, Liu Y, Liu S, Huang X, Li Z, Tan X, Zeng G and Zhou L 2017 Potential Benefits of Biochar in Agricultural Soils: A Review Pedosphere 27 645-61

[19] Putun A E, Ozbay N, Onal E P and Putun E 2005 Fixed-bed pyrolysis of cotton stalk for liquid and solid products Fuel Process. Technol. 86 1207-19

[20] Al-Wabel M I, Al-Omran A, El-Naggar A H, Nadeem M and Usman A R A 2013 Pyrolysis temperature induced changes in characteristics and chemical composition of biochar produced from conocarpus wastes Bioresour. Technol. 131 374-9

[21] Zhang J and Wang Q 2016 Sustainable mechanisms of biochar derived from brewers' spent grain and sewage sludge for ammonia-nitrogen capture J. Clean. Prod. 112 3927-34

[22] Zhang J, Liu J and Liu R 2015 Effects of pyrolysis temperature and heating time on biochar obtained from the pyrolysis of straw and lignosulfonate Bioresour. Technol. 176 288-91

[23] Hossain M K, Strezova V, Chan K Y, Ziolkowski A and Nelson P F 2011 Influence of pyrolysis temperature on production and nutrient properties of wastewater sludge biochar J. Environ. Manage. 92 223-8

[24] Song W and Guo M 2012 Quality variations of poultry litter biochar generated at different pyrolysis temperatures J. Anal. Appl. Pyrolysis 94 138-45

[25] Inguanzo M, Menéndez J., Fuente E and Pis J. 2001 Reactivity of pyrolyzed sewage sludge in air and CO2 J. Anal. Appl. Pyrolysis 58-59 943-54

[26] Abu El-Rub Z A, Bramer E A and Brem G 2008 Experimental comparison of biomass chars with other catalysts for tar reduction Fuel 87 2243-52

[27] Boucher M., Chaala A, Pakdel H and Roy C 2000 Bio-oils obtained by vacuum pyrolysis of softwood bark as a liquid fuel for gas turbines. Part II: Stability and ageing of bio-oil and its blends with methanol and a pyrolytic aqueous phase Biomass and Bioenergy 19 351-61

[28] Kopetz H, Weber T, Palz W, Chartier P and Ferrero G L 1998 Biomass for Energy and Industry: 10th European Conference and Technology Exhibition, proceedings of the International Conference Biomass Energy Ind. 10th Eur. Conf. Technol. Exhib. Proc. Int. Conf. 1829

[29] ISO 10390:2005 Soil quality - Determination of pH - ref-separator -

[30] ISO 11465:1993 Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method - ref-separator -

[31] ISO 14235:1998 Soil quality - Determination of organic carbon by sulfochromic oxidation 5

[32] ISO 11261:1995 Soil quality - Determination of total nitrogen - Modified Kjeldahl method 4

[33] ISO 10694:1995 Preview Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis) - ref-separator -

[34] Chefetz B, Chen Y, Hadar Y and Hatcher P G 1998 Characterization of Dissolved Organic Matter Extracted from Composted Municipal Solid Waste Soil Sci. Soc. Am. J. 62 326

[35] Nelson D W and Sommers L E 1996 Total carbon, organic carbon and organic matter Methods of Soil Analysis. Part 3. Chemical MethodsSoil ed J M Bartels 986-998 (Sci. Soc. Am.)

[36] PND F 16.1:2:3.11-98 Quantitative chemical analysis of soils. Method of conducting measurements of materials in solid objects by spectrometry with ICP - ref-separator -

[37] ISO 13320:2009 Preview Particle size analysis - Laser diffraction methods - ref-separator -

[38] Yuan J H, Xu R K, Wang N and Li J Y 2011 Amendment of Acid Soils with Crop Residues and Biochars Pedosphere 21 302-8

[39] Warnock D D, Lehmann J, Kuyper T W and Rillig M C 2007 Mycorrhizal responses to biochar in soil - concepts and mechanisms Plant Soil 300 9-20

[40] Yuan J-H, Xu R-K and Zhang H 2011 The forms of alkalis in the biochar produced from crop residues at different temperatures Bioresour. Technol. 102 3488-97

[41] Singh B, Singh B P and Cowie A L 2010 Characterisation and evaluation of biochars for their application as a soil amendment Aust. J. Soil Res. 48

[42] Cely P, Gasco G, Paz-Ferreiro J and Méndez A 2015 Agronomic properties of biochars from different manure wastes J. Anal. Appl. Pyrolysis 111 173-82

[43] Zhao B, Xu R, Ma F, Li Y and Wang L 2016 Effects of biochars derived from chicken manure and rape straw on speciation and phytoavailability of Cd to maize in artificially contaminated loess soil J. Environ. Manage. 184 569-74

[44] Li D-C and Jiang H 2017 The thermochemical conversion of non-lignocellulosic biomass to form biochar: A review on characterizations and mechanism elucidation Bioresour. Technol.

[45] Steiner C, Glaser B, Geraldes Teixeira W, Lehmann J, Blum W E H and Zech W 2008 Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal J. Plant Nutr. Soil Sci. 171 893-9

[46] Liang B, Lehmann J, Solomon D, Kinyangi J, Grossman J, O'Neill B, Skjemstad J O, Thies J, Luizão F J, Petersen J and Neves E G 2006 Black Carbon Increases Cation Exchange Capacity in Soils Soil Sci. Soc. Am. J. 70 1719

[47] Gaskin J W, Speir A, Morris L M, Ogden L, Harris K, Lee D and Das K C 2007 Potential for Pyrolysis Char to Affect Soil Moisture and Nutrient Status of a Loamy Sand Soil

[48] Zhao X, Ouyang W, Hao F, Lin C, Wang F, Han S and Geng X 2013 Properties comparison of biochars from corn straw with different pretreatment and sorption behaviour of atrazine Bioresour. Technol. 147 338-44

[49] GOST R 53765-2009 Poultry dung. Raw material for manufacture of organic fertilizers. Specifications - ref-separator -

[50] GOST R 54651-2011 Organic fertilizers on basis of sewage sludge. Specifications - ref-separator -

[51] Inyang M, Gao B, Pullammanappallil P, Ding W and Zimmerman A R 2010 Biochar from anaerobically digested sugarcane bagasse Bioresour. Technol. 101 8868-72